

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)**ScienceDirect**

Transportation Research Procedia 14 (2016) 2344 – 2351



Transportation  
Research  
**Procedia**  
[www.elsevier.com/locate/procedia](http://www.elsevier.com/locate/procedia)

6th Transport Research Arena April 18-21, 2016



# Comparative assessment of public bike sharing systems

Tamás Mátrai <sup>a,\*</sup>, János Tóth <sup>a</sup><sup>a</sup>*BME Department of Transport Technology and Economics, Műegyetem rkp 1-3, Budapest, H-1111*

---

## Abstract

The aim of this paper is to present a comparative assessment among 4th generation Public Bike Sharing (PBS) systems. This article contains a literature review; the development process of the assessment framework as well as it discusses the results and challenges. This article summarizes the already existing Public Bike Sharing Systems and introduces a thorough categorization and a comparison methodology. Additionally, in the last part of this article further research steps will be introduced.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

**Keywords:** Evaluation; bike sharing; impacts; comparative assessment

---

## 1. Introduction

### 1.1. Importance of the topic

According to the UN forecast (United Nations, 2013), the present world population of about 7.2 billion people by 2025 will reach 8.1 billion people, while in 2050, 9.6 billion. The largest increase is expected in the developing regions, while in developed ones, the population is barely growing. Along with this urbanization is expected to increase, which means that the number of urban inhabitants is expected to rise from 3.3 to 6.4 billion. Thus, the total

---

\* Corresponding author. Tel.: +36-20-260-6171.  
E-mail address: [tamas.matrai@mail.bme.hu](mailto:tamas.matrai@mail.bme.hu)

population growth is occurring in urban areas. The proportion of urban population varies according to regions, so 73.4% of Europe's population lives in urban areas with a projection of 80% by 2050 (Buzási and Csete, 2015). Consequently, more and more people use these systems from day to day, hence the pressure on urban transport system is steadily increasing and becoming the major driver of sustainable cities. A high level of transport system is an important precondition of quality change in urban planning which could lead to an increase in living standards (Kampf et al., 2012). Geoffrey West has presented this problem with a different calculation (West, 2011): "For the foreseeable future, until 2050, every week more than a million people are being added to our cities." It clearly shows that the cities will determine the way of life of future generations. The problem of urban transport is exponentially growing with the increase of urbanization. As Robin Chase - founder of Buzzcar - quoted in many of her presentations (Schwartz, 2013) from Banny Banerjee Stanford Professor "You can't solve exponential problems with linear solutions." Public bike sharing can be one of these non-linear solutions, together with other innovative sharing elements.

As transport needs of urban residents have become a socio-economical problem of high importance, urban traffic prediction and modelling is becoming a more and more relevant research area. The various urban transport models can help to make well informed decisions in the future. Traffic modelling is used almost everywhere in the world for the preparation of transport investments. However, limited research is available regarding the incorporation of non-motorized transport modes in these models. With the spread of Public Bike Sharing Systems it is very important to understand the travel behaviour of its users. Until 2001 only some systems exist around the world, while in 2012 this number increased over 400 (Larsen, 2013), in 2014 the number climbed up over 800 (Ricci, 2015), therefore it shows a non-linear growth.

### *1.2. Existing research on characterizing Public Bike Sharing*

There are a large number of scientific articles in international literature available in the topic of bike sharing. Some of them are providing thorough literature reviews such as (Fishman et al., 2013). Others contain datasets about different system characteristics (Midgley, 2011; Shaheen et al., 2012b) but these articles only focus on limited number of parameters or systems, for instance DeMaio's main topic is the business model of PBS systems (DeMaio, 2009). One of the most comprehensive historical reviews and generation descriptions can be found in the (Shaheen et al., 2010) article and it also points out the main research gaps in the field of PBS research.

The linkage between different factors and membership numbers is also a well-studied area (Bonnette, 2007; Corcoran et al., 2014; Fishman et al., 2015), but most of these researches are focusing on Australia, therefore these findings are hardly applicable to Europe. Another problem of these studies is the usually biased samples. A common problem for any type of transport surveys is how to reach non-users.

Other impacts of the PBS systems have extensively been studied as well. Some research focused on the facilitators or the barriers (Fishman et al., 2014, 2012). Another important aspect that has been investigated by health professionals is the perception of cycling and how it is changed due to PBS systems (Goodman et al., 2014). They found that one potential way of normalizing the image of cycling in low-cycling settings is the introduction of bicycle sharing systems. PBS may not only encourage cycling directly by providing bicycles that people can rent but also indirectly by increasing the number and diversity of cycling 'role models' visible. This research can easily be replicable in other cities (e.g. in Budapest) as part of the regular traffic countings thank to its clear methodology and well described process.

Several feasibility studies are available about such systems that are already on the streets or under preparation (COWI, 2010; Department for City Planning New York, 2009; Quay Communications Inc, 2008). The analysis of these studies especially with the comparison of the forecasted volumes to the actual ones can provide additional insight into the impact of bike sharing. This can be also extremely important since real ex-post evaluations are missing.

Finally, the authors (Ricci, 2015) conclude that "Despite the popularity of bike sharing, there is a lack of evidence on existing schemes and whether they achieved their objectives.". Furthermore this paper contains a very comprehensive literature review. In this study the typical user of a bike sharing scheme is identified: "male, white, employed and, compared to the average population in which BSSs are implemented, younger, more affluent, more educated and more likely to be already engaged in cycling independently of bike sharing". This paper also states that

further research is necessary concerning the framework of bike sharing systems' assessment, which is the exact topic of the current paper.

### 1.3. Understanding Public Bike Sharing

Several approaches exist to determine the essence of public bike sharing systems. One of them is the definition of the European Cyclist Federation (ECF, 2012) a Bike Sharing Scheme (BSS): “a self-service, short-term, one-way-capable bike rental offer in public spaces, for several target groups, with network characteristics”. Another interpretation can be the following: “Bike-share programs are networks of public use bicycles distributed around a city for use at low cost. Bicycles can be picked up at any self-serve bike-station and returned to any other bike-station.” (Department for City Planning New York, 2009). While, the Feasibility study of the Mol-Bubi system (COWI, 2010) in Budapest is using the following definition: “Public Bike Sharing (PBS) system is a new kind of alternative public transport service, which is an extension of the conventional public transport system. However, this service can provide flexibility to users same as private transport options. PBS systems provide public bikes for free or very small fee in the frequently used urban spaces. The system can be used for one way trip by anyone.” It is also important to note, that transport professionals use different abbreviations and definitions for the same service (Public-Use Bicycles, Bicycle Transit, Bike sharing, Smart Bikes, Bike Sharing Scheme, Public Bike Sharing), this article applies the expression of Public Bike Sharing (PBS).

The Feasibility study of PBS in Vancouver (Quay Communications Inc, 2008) claims that: “The distance that a person is willing to walk or cycle is dependent on the purpose of journey along with other influencing factors. General planning guidance from the US and UK indicates that people are willing to walk up to 10 minutes for most journey purposes, although they will walk further to access work, up to 2km. Cycling distances generally fall within the 1 km to 5 km range, although, as with walking, people cycling to work have a higher upper threshold at around 8 km.”

The Public Bike Sharing can be situated between walking and public transport, although it is highly different from them. One of the main advantages that PBS users do not need to deal with the bike storage, protection, maintenance, which means that the cost of ownership is not a burden of cycling. Based on the frequency and length of trips, the PBS can be categorized along with other transport alternatives (See Fig. 1). It is mainly used for short distance, occasional travel, therefore it usually does not provide alternatives for commuters. However, these systems can be an option for last mile, provide further transport alternatives, promote cycling in general, boost up safe infrastructure investments and raise awareness.

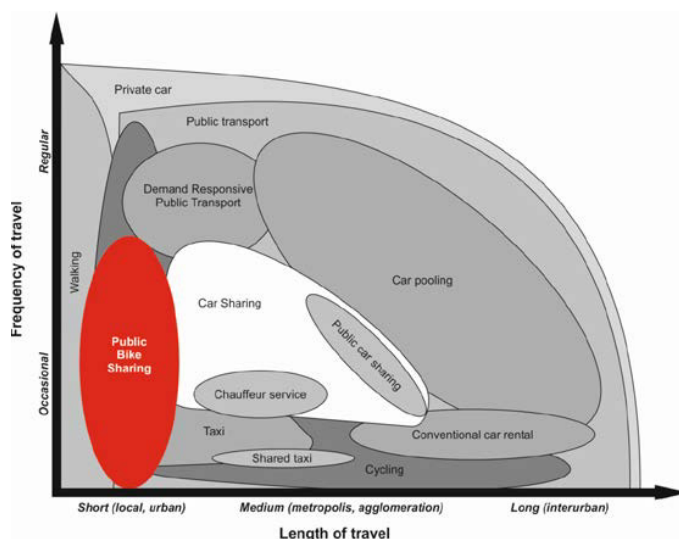


Fig. 1. Comparison of travel alternatives based on frequency and length, (Csiszár, 2009; Tóth and Mátrai, 2015).

#### 1.4. Generations of Public Bike Sharing

The generations of Public Bike Sharing systems have a large literature but the following two publications may cover them in the most comprehensive manner (Midgley, 2011; Shaheen et al., 2010). The authors' previous publications also summarize these in Hungarian; therefore this article only contains a brief overview (see Fig. 2) and some discussion about the fourth generation.



Fig. 2. Generations of PBS systems, (Midgley, 2011; Shaheen et al., 2010; Tóth and Mátrai, 2015).

The novelties of the fourth generation systems are the following:

- high level of integration (urban system, transport system, informatics),
- modularity (easy adaptation to different events, docks can easily be repositioned),
- demand-responsive approach (redistribution, bonus-malus systems),
- increased use of environmental-friendly technologies (solar powered station, electric vehicles)

Usually these PBS systems are integrated into the tariff system of public transport. A further step can be the identification of a PBS user by the same user card as public transport users' one. As these systems have become a major factor in cities' mobility supply, it has been integrated into the urban fabric. With the development of personal information communication technologies it was inevitable that the information provision became real time,

supplemented with the GPS tracking of the bikes. Modularity can be achieved since the solar power and battery technology have rapidly developed in the last couple of years. These technologies provide enough power for the docks and it can be easily repositioned. New mathematical approaches, theories have emerged to solve the large problem of the redistribution of bikes due to the inequalities of demand. With these mathematical processes the redistribution can be more cost-effective; the distribution of the bikes can reflect more on the demand. Additionally, the trial bonus–malus structure of some systems in order to incentivize users to do some redistribution work by themselves. These tariff structures provide bonuses for users who use the system in the opposite direction of the regular flow in a given time (e.g. out-ward from the city centre in the morning peak, upward to the hill). Environment-friendly technologies are not only available on the docking stations but these are also available at the redistribution systems. The vehicles used for this can be built with electric drive or cargo bikes can be used for the same purpose. In order to extend the impact area and to make a PBS system a real alternative, some systems introduced partially or fully electric bikes (Accessible Madrid, 2014).

## **2. Proposed methodology**

### *2.1. Main idea*

This chapter is slightly elaborated at the present stage of our research but the principle of the methodology is deeply deliberated. The lack of comprehensive database about PBS systems in the world does not allow comparing or evaluating them. A guideline does not exist to help planners, experts or decision makers to create a new system or amend an existing one.

The first level of the methodology is gathering data about existing systems. 8 main aspects, about 100 parameters are specified which can describe them in detail. The goal is to create a guideline tool based on this database of 50-100 systems. The existing systems could be categorized by grouping criteria, typical models can be defined as a result. There is no need for all of the parameters in clustering but some derived parameters are considered. Our assumption is that 90% of the systems could be classified into one of the 4-5 clusters. The result is a general method that could identify the type of a certain system irrespective of the fact whether it is an existing system or a proposed one.

The second level of the methodology compiles a SWOT analysis for each clusters based on the examined systems. The strengths, the weaknesses, the opportunities and the threats of the different types of systems are presented. In the creation process of new systems' properties the database and SWOT analysis could help to categorize it and suggest some adjustments. It could help to determine what segments of the system is not sufficiently matured. During this process it is easy to identify the inevitable improvement needs. This tool could provide an opportunity to compile a kind of preliminary feasibility study.

The third level of the methodology, as a benchmark tool, supports the evaluation of systems. The task is to establish a multi-criteria evaluation system based on the selected and weighted base and derived parameters. The results can be different if the user's point of view or the operator's point of view is given the priority. Distinct shortlist of the parameters has to pick out. The position of a system can be determined on a scale. In fact this is a Multiple Criteria Analysis (MCA) a kind of market research.

The fourth level of the methodology is the impact analysis and impact assessment. The existing, conventional methods are not full-featured. Based on the system dynamics approach this tool is a comprehensive methodology guideline. With specifying the parameters of a planned system, the expected impacts can be estimated and quantitative forecast can be given.

### *2.2. Selected cases*

As it was described in Chapter 2.1 the first step is to set up a comprehensive database. This proposed database should consist of eight main parameter categories and the desired sample size should be around 100 different systems. The sample should contain systems from all continents with different size and characteristics. The eight main parameter categories with some example of the first level data are the following:

- Socio-demographic background: e.g. city size, population, climate, topography
- Transport system details: e.g. length of PT network, modal share of different modes, length of dedicated bike infrastructure, number of daily trips
- Base data of the system: e.g. service area size, number of docks, number of bikes, capital costs, annual operating expenditure
- Business model related parameters: e.g. type of the owner, type of the operator, main source of incomes
- Fare system: e.g. annual subscription fee, daily subscription fee, usage fee, integration with other services
- Impact and usage statistics: number of annual users, number of trips, revenue
- Goals: main goal, other goals

The proposed database uses around 100 first level parameters and at least the same number of second level parameters, which are the normalized and combined version of the first level data (e.g. population density, number of trips per bike, revenue generated per trip). As setting up such a database requires large amount of time, this is still under preparation, but in order to have a brief overview some data can be seen in the following tables. Table 1 shows the basic information about the 6 selected systems. These types of data will help to understand the magnitude of each PBS scheme.

Table 1. Basic data of the selected PBS systems.

City name	Lyon	Paris	Montreal	New York	Madrid	Budapest
Name of the system	Velov	Velib	Bixi	Citibike	BiciMAD	MOL Bubi
Number of bikes	3000	20600	5200	6000	1560	1100
Number of station	350	1800	460	332	123	76
Number of docks	n.a.	n.a.	9670	13600	3126	1500
Service area [km <sup>2</sup> ]	n.a.	n.a.	95	53	n.a.	13
Capital costs [million €]	3,9	75,5	15,2	n.a.	25,3	3,6
Annual operating cost [million €]	1,3	29,3	n.a.	n.a.	n.a.	0,1

Table 2 shows some of the fare system parameters of the selected PBS schemes. Additionally to the parameters each system got a complexity point where 1 is the most simple fare system, while 5 is the most complex, hardly understandable one.

Table 2. Basic data about the fare structure of the selected PBS systems.

City name	Lyon	Paris	Montreal	New York	Madrid	Budapest
Name of the system	Velov	Velib	Bixi	citibike	BiciMAD	MOL Bubi
Subscription fee						
Annual subscription fee [€]	25 €	29 €	69 €	83 €	25 €	61 €
Daily subscription fee [€]	1,5 €	1,7 €	6,1 €	8,7 €	free	1,6 €
Deposit for short term users[€/ bike]	n.a	175 €	210 €	n.a	150 €	81 €
Usage fee						
First 30 minutes [€]	free	free	Free	Free	0,5 €	free
Second 30 minutes [€]	0,75 €	1 €	1,45 €	1,1 €	0,6€	1,6 €
Second 60 minutes [€]	3 €	6 €	2,9 €	8,4 €	380	1000
Complexity of the price structure	3	4	3	4	5	4

Table 3 shows some of the business model related parameters. During the literature review it has been found that most of the previous articles (DeMaio, 2009; Fishman et al., 2013; Midgley, 2011; Shaheen et al., 2010, 2012a) often categorized the business model into 3-4 types but did not describe the background of the categorization. We

have to be very careful when discussing different business models as well, since Montreal Bike sharing system's business model seemed excellent until the operator went bankrupt in 2014 (CBC News, 2014; National Post, 2014).

Table 3. Basic data about the business models of the selected PBS systems.

City	Lyon	Paris	Montreal	New York	Madrid	Budapest
Name	Velov	Velib	Bixi	Citibike	BiciMAD	MOL Bubi
Type of the owner	Local Authority	Local Authority	Local Authority	Local Authority	Local Authority	Local Authority
Name of the owner	Grand Lyon	Mairie de Paris	Stationnement de Montreal	NYC Department of Transportation	Madrid City Council	BKK
Type of operator	Local Government / Advertising company	Advertising company	Non-Profit	Service provider	Service provider	Service provider
Name of operator	Grand Lyon / JCDecaux	JCDecaux	PBSC	Alta Bicycle Share	Bonopark	NextBike
Main source of revenue of the system	Advertising	Advertising	User fees	User fee	User fee	Advertising
Who is collecting the user fee?	Owner	Operator	Operator	Operator	Operator	Owner
Does any subsidy in the system?	Yes	No	Yes	Yes	Yes	Yes

### 3. Summary and further research

Unfortunately, there is no comprehensive, worldwide comparative evaluation of the PBS systems. The data about the systems are not available in every cases. This paper illustrates the interim status of the research. The collection of data is the main task. Parallel with this, an elaboration of guidelines is in progress. This tool could bring closer transport experts and decision makers or enthusiastic lobbyist. All of them could use this tool on a different level. The methodology with a detailed list of parameters could be a planning aid and a shortlist of the properties could give a simply comparison of different systems for non-professional users. The principle now is clear but the detailed elaboration is still left, it will be finished in the near future.

Often the worlds of enthusiastic lobbyist and the transport modeller are different. There is a project which is connecting these two worlds. An international consortium have started the FLOW project in May 2015, which is funded under the Horizon2020 programme. This R&D project will help the partner cities not only to enhance the cyclist part of the transport model, but also to share knowledge with other partners, as well as to keep at the frontier of the state-of-the-art modelling practices. Using an enhanced transport model which properly integrates cycling can give the Client the necessary evidence that is needed to convince decision-makers to introduce more cycling and walking measures in urban environment. Providing hard evidence can strengthen the acceptance of adopted measures. Additionally, it is a requirement of the framework of an impact assessment on e.g.: cyclist projects (Tóth and Mátrai, 2015) and traffic calming measures (Juhász, 2013a), (Juhász, 2013b).

### References

- Accessible Madrid, 2014. BiciMAD. The public bike rental service in Madrid [WWW Document]. Access. Madrid website. URL <http://www.accessiblemadrid.com/en/blog/bicimad-public-bike-rental-service-madrid> (accessed 9.24.15).
- Bonnette, B., 2007. The Implementation of a Public-Use Bicycle Program in Philadelphia. University of Pennsylvania.
- Buzási, A., Csete, M., 2015. Sustainability Indicators in Assessing Urban Transport Systems. *Period. Polytech. Transp. Eng.* 43, 138–145. doi:10.3311/PPtr.7825



- CBC News, 2014. Bixi owes \$50M, files for bankruptcy protection - Montreal - [WWW Document]. CBC News website. URL <http://www.cbc.ca/news/canada/montreal/bixi-owes-50m-files-for-bankruptcy-protection-1.2503974> (accessed 9.24.15).
- Corcoran, J., Li, T., Rohde, D., Charles-Edwards, E., Mateo-Babiano, D., 2014. Spatio-temporal patterns of a Public Bicycle Sharing Program: the effect of weather and calendar events. *J. Transp. Geogr.* 41, 292–305. doi:10.1016/j.jtrangeo.2014.09.003
- COWI, 2010. Kerékpáros közösségi közlekedési rendszer kialakítása Budapesten - II. fázisú Megvalósíthatósági tanulmány és költség-haszon elemzés. Budapest.
- Csiszár, C., 2009. Telematikai alapokon működő car sharing rendszer. *Városi Közlekedés* 49, 213–220.
- DeMaio, P., 2009. Bike-sharing: History, impacts, models of provision, and future. *J. Public Transp.* 12, 41–56. doi:10.1016/0965-8564(93)90040-R
- Department for City Planning New York, 2009. Bike-Share - Opportunities in New York City. New York.
- ECF, 2012. Factsheet - The Rise of Bicycle Sharing Schemes. Brussels.
- Fishman, E., Washington, S., Haworth, N., 2012. Barriers and facilitators to public bicycle scheme use: A qualitative approach. *Transp. Res. Part F Traffic Psychol. Behav.* 15, 686–698. doi:10.1016/j.trf.2012.08.002
- Fishman, E., Washington, S., Haworth, N., 2013. Bike Share: A Synthesis of the Literature. *Transp. Rev.*
- Fishman, E., Washington, S., Haworth, N., Mazzei, A., 2014. Barriers to bikesharing: an analysis from Melbourne and Brisbane. *J. Transp. Geogr.* 41, 325–337. doi:10.1016/j.jtrangeo.2014.08.005
- Fishman, E., Washington, S., Haworth, N., Watson, A., 2015. Factors influencing bike share membership: An analysis of Melbourne and Brisbane. *Transp. Res. Part A Policy Pract.* 71, 17–30. doi:10.1016/j.tra.2014.10.021
- Goodman, A., Green, J., Woodcock, J., 2014. The role of bicycle sharing systems in normalising the image of cycling: An observational study of London cyclists. *J. Transp. Heal.* 1, 5–8. doi:10.1016/j.jth.2013.07.001
- Juhász, M., 2013a. Közúti forgalomcsillapítási intézkedések feltételrendszerének vizsgálata, in: *Közlekedéstudományi hallgatói és PhD konferencia*. Győr, p. 1.
- Juhász, M., 2013b. Travel Demand Management – Possibilities of influencing travel behaviour. *Period. Polytech. Transp. Eng.* 41, 45–50. doi:10.3311/PPtr.7096
- Kampf, R., Gašparík, J., Kudláčková, N., 2012. Application of different forms of transport in relation to the process of transport user value creation. *Period. Polytech. Transp. Eng.* 40, 71. doi:10.3311/pp.tr.2012-2.05
- Larsen, J., 2013. Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide [WWW Document]. Plan B. URL [http://www.earth-policy.org/plan\\_b\\_updates/2013/update112](http://www.earth-policy.org/plan_b_updates/2013/update112) (accessed 2.18.15).
- Midgley, P., 2011. Bicycle-Sharing Schemes: Enhancing Sustainable Mobility in Urban Areas. *Comm. Sustain. Dev.* 19th Sessi, 1–26.
- National Post, 2014. Bixi bike-sharing company filing for bankruptcy protection, Montreal mayor rejects another bailout [WWW Document]. Natl. Post website. URL <http://news.nationalpost.com/news/canada/bixi-bike-sharing-company-filing-for-bankruptcy-protection-montreal-mayor-rejects-another-bailout> (accessed 9.24.15).
- Quay Communications Inc, 2008. TransLink Public Bike System Feasibility Study. Vancouver.
- Ricci, M., 2015. Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Res. Transp. Bus. Manag.* 15, 28–38. doi:10.1016/j.rtbm.2015.03.003
- Schwartz, A., 2013. Zipcar's Co-Founder: Carsharing Is An Exponential Solution To Climate Change [WWW Document]. URL <http://www.fastcoexist.com/1681927/zipcars-co-founder-carsharing-is-an-exponential-solution-to-climate-change>
- Shaheen, S., Guzman, S., Zhang, H., 2010. Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future, in: *TRB Annual Meeting*. pp. 1–20.
- Shaheen, S.A., Mallery, M.A., Kingsley, K.J., 2012a. Personal vehicle sharing services in North America. *Res. Transp. Bus. Manag.* 3, 71–81. doi:10.1016/j.rtbm.2012.04.005
- Shaheen, S.A., Martin, E.W., Chan, N.D., 2012b. Public Bikesharing in North America: Early Operator and User Understanding, *MTI Report* 11-19. Mineta Transp. Inst. Publ.
- Tóth, J., Mátrai, T., 2015. Újszerű, nem motorizált közlekedési megoldások, in: *Közlekedéstudományi Konferencia*. Győr.
- United Nations, 2013. *World Population Prospects The 2012 Revision Volume I: Comprehensive Tables*. New York.
- West, G., 2011. *The surprising math of cities and corporations*.